Installing Electric Meters at Navy Facilities: Benefits and Costs

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CRM D0008909.A2 / Final
November 2003

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE **NOV 2003**	2. REPORT TYPE	3. DATES COVERED **00-00-2003 to 00-00-2003**
4. TITLE AND SUBTITLE **Installing Electric Meters at Navy Facilities: Benefits and Costs**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **CNA,4825 Mark Center Drive,Alexandria,VA,22311**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**64**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Approved for distribution: November 2003

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This document represents the best opinion of CNA at the time of issue.
It does not necessarily represent the opinion of the Department of the Navy.

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Summary

Motivation

Later this year, Congress is expected to pass legislation to require all federal facilities to have advanced electric meters "to the maximum extent possible." The Navy needs to determine the most cost-effective way to comply with this requirement.

Benefits of metering

Advanced electric meters can be very helpful to energy managers. Information from weekly electricity-consumption profiles can help identify many areas of potential savings, including:

- Identifying equipment left on during non-working hours
- Shifting electricity usage to less expensive off-peak periods
- Comparing energy usage between similar buildings to identify problems
- Measuring bottom-line electricity savings from energy conservation projects.

How much can the Navy save using advanced meters in a military environment under current management incentives?

Evidence from San Diego

The Navy has more than 1,000 buildings connected to advanced meters in San Diego. Regression analysis of billing data shows that metering buildings can save significant amounts. Buildings with advanced meters consumed 5-percent less electricity. Because this savings was predominantly in high-cost peak periods, metered buildings cut electricity costs by 9 percent.

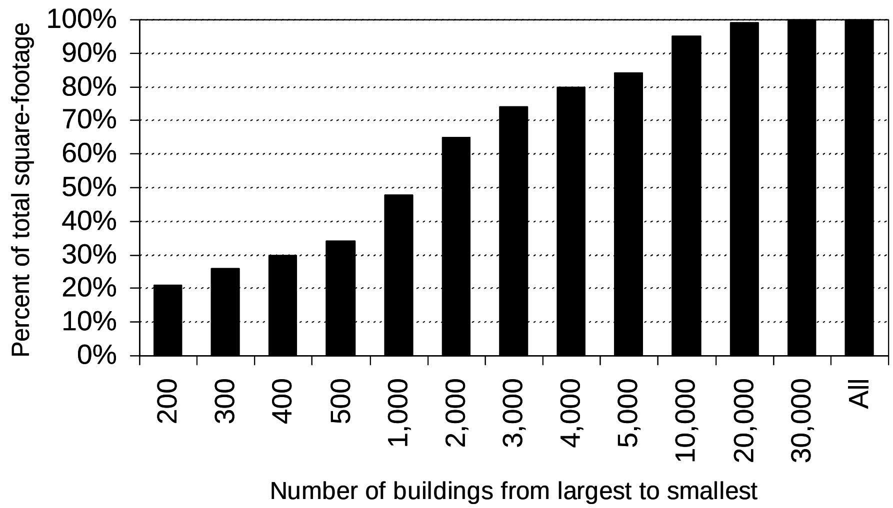
Costs of metering

The costs of metering for the Navy may be high. The Naval Facilities Engineering Command estimates that it costs $5,000 to purchase and install a new meter. The Navy may have certain unique requirements that would justify such a high cost. In addition, each building may have multiple feeds to be metered. Although these cost estimates are high, the savings justify metering many Navy buildings.

How many buildings to meter?

By metering its largest buildings, the Navy can meter most of its square-footage and cost-effectively fulfill the congressional requirement. Figure 1 shows the percentage of total square-footage in the United States encompassed by the largest Navy buildings.

Figure 1. Percentage of square-footage included in the largest Navy buildings in the United States (excluding family housing)



The largest 200 buildings account for over 20 percent of all Navy building square-footage in the United States. The largest 2,000 buildings account for almost two-thirds of the total square-footage.

The most cost-effective metering decisions need to be made using local data. However, by metering its largest buildings, it is probably practical for the Navy to meter between 60 and 80 percent of its total building square-footage in the United States, excluding family housing. Adjusting for those buildings (in San Diego) that have already been metered, higher-bound estimates for costs are between $22 and $55 million.

Management incentives matter

Management incentives affect how effectively data from advanced meters will be used. The regression analysis from San Diego showed that regionalized and working capital fund activities showed additional savings, beyond those described above, when compared with non-regionalized, mission-funded activities.

Getting the most out of the metered data will require that activities see the true costs of their decisions. Utility prices and rate structures need to be realistic. The utility industry is moving toward peak-load pricing and real-time pricing. The same congressional legislation will require that utilities offer these options to customers. Advanced meters are designed to help customers maximize the benefits from these rate structures. The Navy needs to move in this direction also.

Navy entities that pay utility bills should also be responsible for making energy improvements. They need to see the true cost tradeoffs between conservation investments and long-term savings. These activities should be able to keep some of the savings from conservation. Currently, savings may be kept in the short term within the fiscal year, but are typically taken away in subsequent years. Activities should be allowed to keep some of the savings for several years.

Introduction

In the near future, Congress is expected to give final approval to legislation that will require electric meters to be installed on federal facilities. Both houses of Congress have passed omnibus energy bills[1] which are presently being considered by a conference committee.

Both versions of the bill contain provisions that "all Federal buildings shall, for the purposes of efficient use of energy and reduction in the cost of electricity used in such buildings, be metered or submetered." The bills go on to specify that "Each agency shall use, to the maximum extent practicable, advanced meters or advanced metering devices that provide data at least daily and that measure at least hourly consumption of electricity in the Federal buildings of the agency. Such data shall be incorporated into existing Federal energy tracking systems and made available to Federal facility energy managers" [1, 2].

Both bills call for implementation guidelines to be established by the Department of Energy "in consultation with the Department of Defense, the General Services Administration and representatives from the metering industry, utility industry, energy services industry, energy efficiency industry, national laboratories, universities and Federal facility energy managers" within 180 days of enactment. These guidelines must take into consideration "the cost of metering and submetering and the reduced cost of operation and maintenance expected to result from metering and submetering."

The deadline for implementing the metering requirements is October 1, 2010 in the House version. The Senate version deadline, as

1. Different versions of H.R. 6, the Energy Policy Act of 2003, passed both houses of Congress. The House of Representatives passed its version on April 11, 2003; the Senate, on July 31, 2003.

reported by the Library of Congress, Thomas Internet system is October 1, 2004.

The Director of the Navy Ashore Readiness Division (OPNAV N46) asked CNA to examine the benefits and costs of metering and to incorporate them into an implementation strategy. CNA is also to suggest ways to maximize the effective use of data generated by the new meters. The purpose of this paper is to help prepare the Navy to implement the legislation and to provide data to help support the Navy in the 6-month consultation period envisioned by the bills.

We begin by discussing and quantifying the benefits from metering. We then go on to discuss the costs of metering. In the third part, we discuss guidelines to estimate which buildings will be cost-effective to meter and how to get the most from the data generated by meters. In the fourth part, we compare the overall budgetary costs and benefits from metering. The fifth part is the conclusion. There is also an appendix containing the specifications and results of the regression analyses used to estimate benefits.

Acknowledgments

We are grateful for the help, guidance, and support of LCDR Lore Aguayo, Mr. Wade Wilhelm, Mr. John W. Thomas, Ms. Mary E. Harshberger, and Mr. Mark E. Johnson.

Benefits of metering

Overall benefits

Information from demand-interval meters is potentially very important to energy managers.[2] Examining a weekly energy-use profile can help identify potential savings. For example, it becomes obvious if equipment is unnecessarily being left on during non-working hours. Comparisons can be made between the energy consumption profiles of similar buildings to help find maintenance and equipment problems.

Many utilities have rate structures based on peak and off-peak prices and power demand levels. Examining a daily electricity-use profile can help identify ways to shift consumption from peak to off-peak periods and help keep demand levels below contracted thresholds.

Meters can help measure the effects of installing new energy-efficient technologies. Without meters, engineering estimates often serve as the main basis for verifying savings. Meters can help give a bottom-line estimate of the savings from these technologies. The best ones can then be replicated throughout the service, and ineffective programs can be stopped.

Meters also improve cost visibility. When costs are not accurately known, there is a tendency to overlook them. Activities and individuals have little incentive to conserve electricity if those efforts are neither rewarded nor even measured.

2. In this paper, we will use the terms, "demand-interval meter" and "advanced meter" to indicate meters that can track electricity usage throughout the day and will satisfy the requirements contained in the congressional legislation. Sometimes, we will refer to these meters as "saving" money or electricity. What is meant by this term is that the information from these meters can help energy managers make better decisions and take actions that result in savings.

Quantifying the benefits

Although much of the trade literature agrees that information from metering can be very helpful, accurately quantifying the benefits has been difficult. Informal estimates from the private sector show that advanced meters typically save from 5 to 25 percent of electric costs, with most buildings showing between 10- and 20-percent savings [3].

In addition, there are case studies in the literature that show various levels of savings, but these, by their nature, tend to be anecdotal. We have not been able to find a rigorous estimate of the savings that can be expected from a broad-based installation of demand-interval meters as envisioned by the federal legislation.

It is also not clear that private-sector estimates are truly applicable to the government. Government activities have very different budgetary restrictions and management incentives than the private sector [4]. Even if government managers have the same energy information as private managers, they may not be able to act on it. Unless the initiative includes management reform, it is inappropriate to make simple comparisons between private entities and the government. What is needed is an examination of how the government—and more specifically, the military—is able to use the data from demand-interval meters to improve energy efficiency.

Examination of data from San Diego

The Navy has an excellent example of how demand-interval meters can be used in a military environment with current management incentives. The Public Works Center (PWC) in San Diego has been installing demand-interval meters for military facilities for the last several years. They use this information to provide their customers with accurate bills and their full electricity-usage patterns via a Web-based software system, MV-Web.[3] Because of the generally high electricity

3. MV-Web refers to "Multi-Vendor" Web software because it is compatible with metering devices from many manufacturers.

costs in the region and the PWC's realistic pricing schedule, activities have strong incentives to make use of these data.

We were able to analyze 6 years of monthly billing data from March 1997 through March 2003 for facilities in the San Diego area. We have data for about 1,500 main building facilities and about 500 smaller sub-facilities for a total of about 2,000 buildings. Currently, we estimate that about 1150 of these are attached to demand-interval meters.

The results of the regression analyses were highly significant. The appendix contains the detailed specifications. After adjusting for a building's fixed characteristics and monthly effects covering all of San Diego (such as weather), buildings used 5-percent fewer kilowatt-hours (kWh) of electricity after demand-interval meters were installed. The 95-percent confidence interval for the estimation ranged from 3 to 7 percent savings.

When we examined the cost of electricity used, buildings used 9-percent less electricity in dollars after demand-interval meters were installed. The 95-percent confidence interval for the estimation ranged from 6.5-percent to 11.5-percent savings.

The difference between the cost and kWh savings is because the advanced metering helped energy managers reduce usage disproportionately during the higher-priced peak and semi-peak rate periods. Table 1 shows the kWh savings from demand-interval meters during the different rate periods. San Diego has a complex rate structure with three basic time periods that vary between summer and winter. The appendix contains detailed descriptions of these time periods.

In addition to the overall electricity used (kWh), customers are charged for momentary power (kW) demand levels coinciding with the local utility's and the Navy's peak demand periods. Table 2 shows that those buildings with demand-interval meters are able to reduce their electric power demand levels. Definitions of these momentary power demand levels are contained in the appendix.

Table 1. Kilowatt-hour savings patterns for San Diego buildings with demand-interval meters

Rate period	Summer savings	Winter savings
Off-peak	Insignificant savings	Insignificant savings
Semi-peak	Insignificant increases	6-percent savings
Peak	9.5-percent savings	7-percent savings
Overall kWh usage	4-percent savings	6-percent savings

Table 2. Kilowatt savings patterns for San Diego buildings with demand-interval meters during coincident and non-coincident demand periods

Demand period	Summer savings	Winter savings
Building power demand (kW) when local utility is at monthly peak (coincident demand)	7.5-percent savings	14-percent savings
Building power demand (kW) when Navy facilities are consuming at monthly peak (non-coincident demand)	8-percent savings	10-percent savings

Applying the results

Because much of the cost savings appears to come from the rate structure in San Diego, the Navy may not be able to achieve the same level of savings everywhere from installing demand-interval meters. In localities with peak-load pricing, we would expect savings similar to the 9 percent achieved in San Diego.

In localities where the utility offers only one electricity rate throughout the day, we would expect the savings to be closer to the 5-percent reduction in kWh experienced in San Diego. In this case, a 5-percent reduction in kWh's used would likely result in a 5-percent reduction in overall costs. This is probably a good lower-bound estimate for potential savings.[4] Table 3 summarizes the application of these results to other localities.

Table 3. Estimating the benefits of installing demand-interval meters in different localities

Description of local rate structure	Potential cost savings from electricity usage
Simplified rate structure: one electricity usage rate throughout the day	5 percent savings
Realistic rate structure: peak-load pricing for kWh usage and demand rates for kW peaks	9 percent savings

Are savings merely the effect of energy conservation investments?

In 2000 and 2001, there were energy crises in San Diego and then throughout California. To save electricity, the Navy made many conservation investments in its facilities. We were concerned that these investments might have been made disproportionately on those buildings with the demand-interval meters and that this might account for the results. However, most of these conservation contracts were signed after 2000, and they only began to be implemented at the end of FY 2001. We looked at the savings rate for buildings with demand-interval meters before and after 2000, 2001, and 2002. The savings from these meters were fairly uniform throughout the time frame and were not significantly different in these periods. These results argue strongly that the savings from metering were not due to

4. The utilities industry is moving toward more peak-load and real-time pricing. The congressional legislation requiring meters on federal facilities also requires public utilities to offer peak-load pricing and real-time pricing options to customers [5, 6]. Although 5 percent is currently a good lower bound for estimated savings from demand-interval meters, the savings achieved will likely increase over time as more utilities offer new pricing options.

the energy crisis, its political effects, or a disproportionate share of conservation investments.

Effect of management structures

Different Navy activities in the San Diego area have different management structures. There are regionalized activities and working capital fund activities, along with non-regionalized, mission-funded activities. We included parameters to test the savings from these various management structures.

We found that both the regionalized and working capital fund activities used less electricity than did the non-regionalized, mission-funded activities. Buildings occupied by regionalized activities showed a 12-percent reduction in electricity usage (kWh) and an 8-percent reduction in electricity cost. Working capital fund buildings showed a 13-percent reduction in both electricity usage (kWh) and cost. These savings levels were separate from the savings achieved from utilizing information from the demand-interval meters.

These results were driven by the fact that there was a large turnover of building tenants in the San Diego region during our data period. Hence, we could observe the same building being occupied by different classes of tenants. What we don't know is whether regionalized and working capital fund activities are using their buildings as intensively as are the non-regionalized, mission-funded activities; the implicit assumption is that they are.

Additional benefits from metering

Meters can also help managers make better decisions regarding new equipment and conservation technologies. Measuring the bottom-line effect of these investments on energy costs can provide valuable data to ensure that resources go to the most cost-effective energy initiatives.

Often, energy efficiency investments are based on engineering estimates. Because buildings are not metered, nobody knows for sure whether those savings are ever actually realized. Sometimes, these engineering estimates have been shown to be incorrect. For example, the NavFac headquarters building at the Washington Navy Yard was completely renovated in 1997 and 1998 using sustainable design and "building within a building" concepts. Engineering models predicted a savings of 30 percent compared to a base case design [7]. A study of the building's energy usage in 2001 found a savings of only 15 percent [8].

The Navy uses energy savings performance contracts (ESPCs) to install some of its conservation equipment. These contracts require monitoring and verification reports that can include metering. However, the examples provided to us used meters to partially augment engineering estimates, not to measure bottom-line usage [9, 10, 11]. Investments in these cases were for new lighting fixtures.[5] The meters were used to sample and verify the manufacturer's power specifications; the rest of the savings analysis was based on engineering estimates. A shortcoming of this methodology is that it doesn't measure any secondary and overall effects. For example, if the new lighting is inadequate, occupants will use supplemental lighting sources; conversely if the new lighting levels are an improvement, occupants may turn off some previously used lighting. Another secondary effect is that lower wattage fixtures will generate less heat and could lower air conditioning costs. One study [11] did take this last effect into account through engineering estimates, but not by actual energy cost measurements.

It is this type of bottom-line savings after adjusting for behavior that building meters can help estimate. It is especially important for initiatives that may be replicated at multiple locations. Meters may be able to demonstrate what type of innovations have the biggest bottom-line payoffs under real-world, Navy working conditions.

5. One of the reports [11] did use meters to verify the savings from a new chiller plant. Meters have been used to measure output and savings from generation facilities, such as power plant upgrades and chiller plants [12, 13], but we did not find evidence that meters verified the bottom-line savings from conservation investments in non-generating facilities, such as office buildings, housing, etc.

Costs of metering

There are three major components to estimating the cost to implement the legislation:

- The cost to install, maintain, and monitor a demand-interval meter
- The number of electrical feeds per building that must be metered
- The number of buildings required to be metered.

We will discuss each of these components in turn and then derive overall cost estimates for installing meters.

Cost per meter

The Naval Facilities Engineering Service Center (NFESC) at Port Hueneme estimates that it costs about $5,000 to purchase and install a demand-interval meter consistent with the legislative requirements. This estimate was based on the cost of installing meters at NSWC Crane and NAF El Centro in new locations.

We examined the product literature for meters and spoke to some people in the field. Most quoted much lower prices, sometimes just a few hundred dollars per meter. However, without a full engineering review, it is difficult to know the precise capabilities of these meters and whether they will actually meet the military's needs.

We did find two studies that discussed large-scale installation of advanced meters in the private sector [3, 14]. The estimated costs in these studies were from $2,000 to $2,300 per installed meter.

However, even these costs may not be equivalent to the military's costs. These studies involved taking an existing meter and replacing it with a more advanced one. Often at Navy bases, there are no existing meters. Installing a new meter in a new location may be more expensive.[6] NFESC has told us that sometimes it is not even known where the electrical feeds are for a building; much of the installation expense may be due to tracing how the buildings are connected to outside power lines. We do not know which Navy buildings are in this situation. These are unique costs, without a private sector equivalent, that probably need to be estimated on a case-by-case basis.

Therefore, in this paper, we are going to be conservative and use the estimated $5,000 cost to purchase and install a meter.

Maintenance and meter-reading costs

The Public Works Center in San Diego reported that their meters are very reliable and require almost no maintenance. For meter reading, they have a contract with San Diego Gas & Electric which reads the demand-interval meters with hand-held computers. The cost of reading those meters are $1.35 per meter per month or about $16 per year.

Other costs

There are other costs for the meters. Currently, there is an issue about whether the meters need to be connected through the Navy-Marine Corps Intranet (NMCI) and precisely how much that would cost. This is subject to negotiation between the Navy and the NMCI contractor. We will not deal with that cost here; when the issue is decided, it will have to be added to the cost estimates in this paper.

In addition, there are software costs for monitoring data from the new demand-interval meters. These costs are very difficult to assess.

6. The Navy recently surveyed its facilities and found that roughly 70 percent of its building are not metered. Most of the remaining 30 percent of buildings have older, monthly meters that would have to be replaced under the new legislation. We do not have detailed estimates about how much it costs the Navy to replace an existing meter. Therefore, to be conservative, we will assume that replacing an existing meter costs the same as installing one in a new location. This means that the cost estimates in this paper are likely to be higher-bound estimates.

The Navy already owns software (CUBIC and MV-Web) for this purpose in San Diego. That software can be licensed and installed at other locations. All the Navy's utility activities currently need to run some software; it is not known how the costs and maintenance for the existing software compare to costs for the CUBIC and MV-Web software.

Other alternatives

The legislative mandate can be met not just with meters, but with "advanced metering devices." Many types of meters can be retrofitted with devices to read the meter at frequent intervals and transmit that data to a remote location. Where feasible, this approach is a far more cost-effective strategy for satisfying the legislation. However, at the present time, we do not know how many of the Navy's existing meters are compatible with these retrofitted devices.

Number of electrical feeds per building

One unknown factor in estimating costs is the average number of electrical feeds per building. To fully meter a building, all electrical feeds need to have meters. These meters must also be coordinated to obtain accurate readings.

This is an important factor because the number of feeds geometrically affects the costs. We do not know how many feeds there are to meter in Navy buildings. The number of feeds appears to be correlated with the size and age of a building. Larger and older buildings seem to have more electrical feeds.

From the San Diego PWC data, we estimate that those buildings with demand-interval meters have an average of 3 feeds per building.[7] A recently completed survey of Navy buildings in the U.S. estimated that there were 1.2 feeds on average for buildings already metered (either with monthly meters or demand-interval meters). However,

7. The precise mapping of buildings and meters was not totally clear from the CUBIC data, which is why the 3 feeds per building average is only an estimate.

we do not know whether these Navy-wide metered buildings are representative of all Navy buildings, as newly constructed buildings often include meters and have fewer feeds than older Navy buildings. Therefore, to be highly conservative, we will use the San Diego estimate of 3 feeds per building to derive the base case cost estimates in this paper.

It should be noted that when estimating costs on a local level for a specific military base, buildings should be inspected to determine the precise number of feeds.

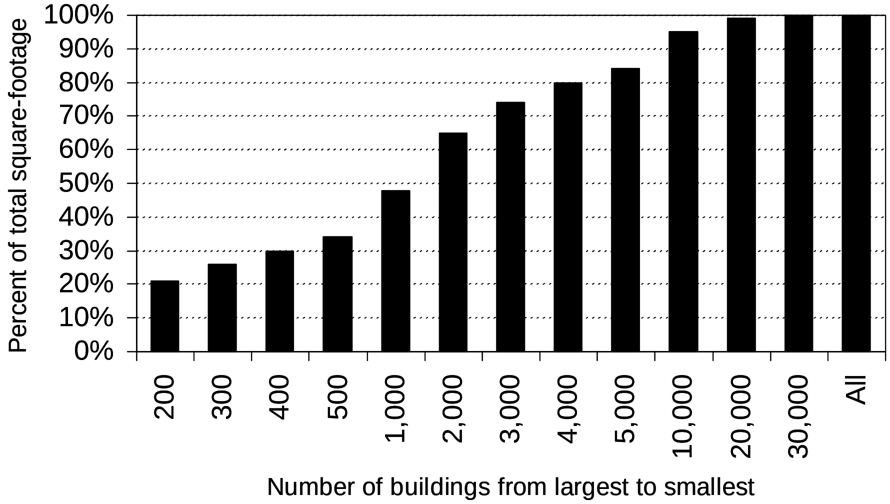
Number of buildings to be metered

According to data from the Internet Navy Facilities Asset Data Store (iNFADS), in July 2003, the Navy had about 50,500 buildings in the United States and almost 63,000 buildings worldwide.[8] If we exclude family housing, those numbers drop to about 30,400 buildings in the United States and 39,000 buildings worldwide.

Figure 2 shows the percentage of total square-footage encompassed by the largest Navy buildings in the United States excluding family housing.[9] The largest 2,000 Navy buildings account for almost two-thirds of the total Navy square-footage in the United States according to iNFADS. The largest 3,000 buildings account for almost three-quarters of the Navy square footage. Hence, by metering its largest buildings, the Navy can effectively meter most of its square-footage.[10]

8. This excludes buildings designated to be closed through BRAC.
9. Currently, the Navy is in the process of privatizing much of its family housing. Metering those units would probably be best accomplished as part of that privatization initiative.
10. Ideally, the Navy will want to meter its largest users of electricity (in terms of cost). We did not have access to engineering estimates of the amount of electricity each building in the Navy uses. Therefore, we are using square-footage as a proxy to estimate the relative use of electricity across buildings.

Figure 2. Percentage of square-footage included in the largest Navy buildings in the United States (excluding family housing)



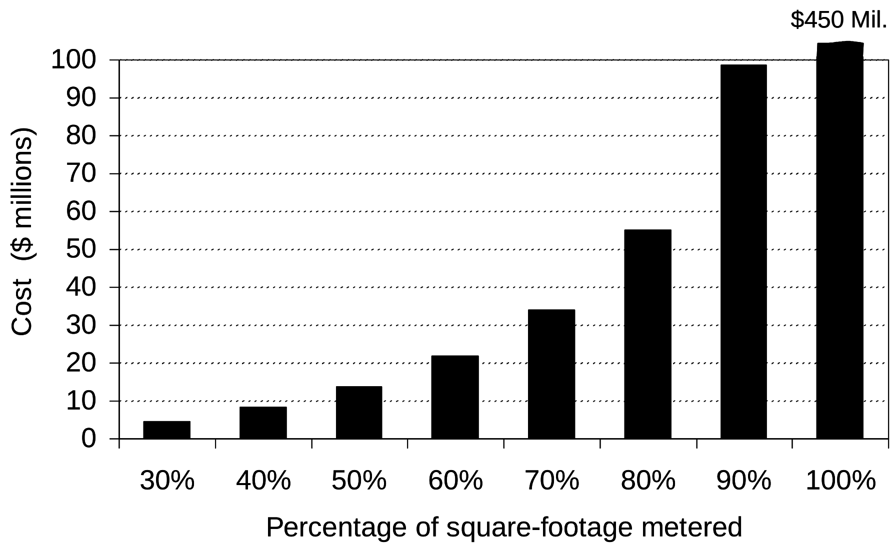
Cost estimates for implementing the legislation

From the previous discussion, we can estimate the cost to meter different percentages of the total square-footage of Navy buildings in the United States.[11] We assume that each building has three electric feeds to be metered at a cost of $5,000 per feed, and that only the largest buildings will be metered. Also, we have adjusted the cost estimates to take into account those buildings in San Diego which already have demand-interval meters.

Figure 3 shows the estimated cost to meter different percentages of overall square-footage. To meter 60 percent of the square-footage of Navy buildings in the United States would cost about $22 million. To meter 80 percent would cost about $55 million. Metering 90 percent or more of the Navy's square-footage causes the cost to skyrocket as the remaining buildings decrease in size.

11. Excluding family housing.

Figure 3. Estimated cost to meter different percentages of the square-footage of Navy buildings in the United States (excluding family housing)[a]



a. Estimates have been adjusted to account for buildings known to already have demand-interval meters.

Cost estimates using alternative assumptions

Metering 80 percent of the square-footage of Navy buildings (excluding family housing) requires metering all buildings larger than 17,000 square-feet. Table 4 shows how much this would cost under different sets of assumptions.

Table 4. Estimated cost to meter Navy buildings over 17,000 square-feet (covering 80 percent of all Navy building square-footage in the United States) under different assumptions

Assumptions	Estimated cost
Average installation cost: $5,000 per meter Average number of feeds per building: 3	$55 million
Average installation cost: $2,500 per meter Average number of feeds per building: 3	$28 million
Average installation cost: $5,000 per meter Average number of feeds per building: 1.2	$22 million
Average installation cost: $2,500 per meter Average number of feeds per building: 1.2	$11 million

Implementation guidance

The Federal Energy Management Program (FEMP) gives some general guidelines for metering [15]. They suggest metering only those buildings with electrical demands over 200 kW. Also metering may not be justified in buildings with annual electric bills of less than $1,000.

The data and analysis in the previous sections allow us to go beyond FEMP and suggest more detailed guidance.

Priority of metering

As a general rule of thumb, a military base should meter its largest users of electricity first. Unless a building has an extraordinarily high number of electrical feeds to be metered, it is best to meter the largest buildings first, because they are likely to offer the greatest opportunity for savings.

The final legislation is expected to permit a multi-year window for metering facilities. There should be time for a roll-out, so that a base can gather data on costs and achieved savings. These data can be used as input into net-present-value (NPV) calculations, as described below, to determine precisely which buildings should be metered. By examining lessons learned from metering its largest buildings first, a base can determine the size that a building must be to optimally justify demand-interval metering in its locality.

NPV rules for metering

When making an economic decision about whether to meter a specific building, that decision should be based on a net-present-value calculation. If the NPV is positive, it is cost-effective to install demand-interval meters; if it is negative, demand-interval meters are not cost-effective. Wherever possible, this calculation should be made with estimates tailored to a specific building and location.

The net-present-value equation that should be used is

$$\textit{Net present value} = -(\textit{Number of feeds} \cdot \textit{Installation cost})$$

$$+ \sum_{t=1}^{T} \left(\frac{(\textit{Savings rate} \cdot \textit{Electricity cost}) - (\textit{Number of feeds} \cdot \textit{Reading cost})}{(1 + \textit{Discount rate})^{t}} \right)$$

Where:

Number of feeds is the number of electrical feeds to the building that need to be metered. In this paper, we assume that number, on average, is 3, but when making an actual decision, the correct number should be used.

Installation cost is the estimated cost to purchase and install a meter. For this paper, we are assuming that cost to be $5,000 per meter. However, the true estimated cost should be used. This true cost may vary: If a monthly meter is already installed, the cost may be less; if that meter is compatible with an auxiliary reading device, it may be less still.

Savings rate is the estimated savings expected from installing the demand-interval meter. A good lower-bound estimate for this rate is 5 percent.[12] If the local electricity rate structure is similar to that of

12. Some may object to applying the estimates from San Diego to other locations. Indeed, if better local data are available, they should certainly be used. However, as of the writing of this paper, the only rigorous estimates available for savings for demand-interval meters in the Navy are the data from San Diego. The alternative estimates we've seen have been based on conjecture. The 5-percent savings estimate is a lower-bound estimate based on the data. As more utilities offer peak-load and real-time pricing, the savings estimate is likely to grow closer to the 9-percent cost savings found in San Diego.

San Diego with high peak-load costs, then a higher savings rate, closer to 9 percent, would be appropriate.

Electricity cost is the total estimated annual electricity cost currently used by the building.

Reading cost is the estimated annual cost to read the meter. If the costs are similar to those at the PWC San Diego, the cost should be about $16 per year.

Discount rate is the standard government discount rate at the time for a project. For this paper, we are going to use 5 percent.

T is the expected life of the electric meter.

Electric meters are typically very reliable. In the limiting case where the electric meter is expected to last forever, then the NPV equation reduces to

$$Net\ present\ value = -\ (Number\ of\ feeds \cdot Installation\ cost)$$
$$+ \left(\frac{(Savings\ rate \cdot Electricity\ cost) - (Number\ of\ feeds \cdot Reading\ cost)}{Discount\ rate}\right)$$

Using the assumptions in this paper and the lower-bound estimated savings rate of 5 percent, we can calculate the threshold at which it becomes cost-effective to install demand-interval meters in buildings. Table 5 shows the minimum estimated annual electricity cost for installing demand-interval meters for building by the number of electrical feeds to be metered. As noted above, true costs and benefits may vary between buildings and bases, and local data should be used in the calculations wherever possible.

Table 5. Estimated thresholds for installing demand-interval meters at Navy buildings[a]

Number of electrical feeds to building	Meter if estimated annual electric bill is over
1	$ 8,000
2	17,000
3	25,000
4	33,000
5	42,000

a. Estimated values assume: (1) $5,000 per meter installation cost; (2) Expected 5 percent electricity cost savings; (3) $16 annual cost to read each meter; (4) 5% discount rate; and (5) Expected life of meter will be 20 years.

Getting the most out of the information from metering

Lessons from San Diego

We spoke to officials at the PWC San Diego to determine what factors are important to encourage activities to get the most out of their metering data. These factors include:

- Cost visibility
- Resource efficiency managers
- Seeing trade-offs between energy investments and electrical consumption.

The most important factor appears to be having a realistic rate structure. The electrical rates charged by the PWC San Diego have several components that reflect the rates and structure set by the local utility. Tenants get to see each component of their bill. They also get to see their building's electricity usage profile. This full cost visibility and consumption visibility help to encourage savings.

Simplifying billing rates would send the wrong signals. Advanced meters provide a large amount of detail about electrical demand. Tenants need to know the full detail about electrical supply costs in order to reap the most benefits.

In San Diego, the regionalized and working capital fund activities often have Resource Efficiency Managers (REMs) to help identify and coordinate energy savings projects. The REMs are generally private contractors whose goals are to save the government twice as much as the contracts cost. Their responsibilities include reviewing and analyzing meter data, training building occupants to utilize the meter data, and working with them to identify low-cost and no-cost ways to improve operations. These REMs are part of the reason we found additional savings for the regionalized and working capital fund activities. However, savings from demand-interval meters were evident for all types of activity classifications.

Finally, it's very important that the entity that is responsible for paying the electric bills is also responsible for energy improvements. These activities should be able to see the trade-offs between conservation and equipment investments and electrical costs. They cannot be buried in separate accounts; the trade-offs must be visible.

Improving other incentives and processes

Budgeting processes need to be changed so that activities that conserve energy can keep some of the savings. In San Diego, activities that conserve get to keep the savings for that fiscal year, but, in general, subsequent savings will be taken away. Activities ought to be able to keep some of the savings for a few fiscal years.

We have also heard that there have sometimes been letters of agreement that reduce the costs to activities that overuse utilities. If these are still in effect in certain locales, they need to be changed. Activities need to be able to see the full costs of their consumption; inputs that appear to be free or subsidized will be overused.

Local utility companies frequently offer various rate structures to their larger customers.[13] Without meters, bases do not know when they are consuming power, and it, therefore, may be optimal to have a flat rate structure. However, with demand-interval meters, it becomes possible to track consumption, and different rate structures may be optimal. If the San Diego region had had a flat rate structure, users could have saved only 5 percent from demand-interval meters, but because the rates included peak-load pricing and demand charges, they were able to save 9 percent. As bases install more and more demand-interval meters, their contracts with local utilities will need to be reexamined to make sure they provide the greatest benefits to the Navy.

Finally, bases that are installing meters may want to consider having automated communications from those feeds. These connections may provide automatic alarms when electrical consumption reaches set thresholds, or systems can even be set to automatically reduce loads to keep below certain thresholds. In the future, some expect that real-time electricity prices will be used which would require meters to automatically convey cost information and electrical systems to automatically adjust. At some point, the Navy may want to consider these capabilities, but that is beyond the scope of this paper.

13. Both versions of the energy legislation being considered by Congress require that public utilities make a time-of-use rate schedule and real-time pricing options available to customers who request it [5, 6].

Comparing overall costs with benefits

In this section, we make a broad monetary comparison between the overall costs and benefits of metering. These are rough numbers designed to estimate the percentage of building square-footage which is cost-effective to meter.

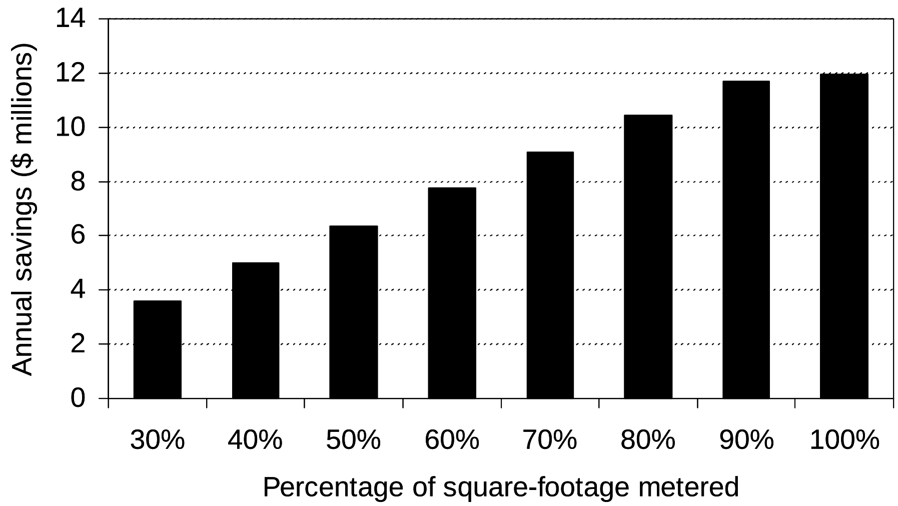
We were able to obtain only the very highest level estimates for total Navy electricity consumption and costs in the United States. These data were reported in the NavFac metering survey but were derived from the Defense Utility Energy Reporting System (DUERS). At least one previous study has criticized the accuracy of these DUERS data [16]. They were estimated by summing the electrical energy used throughout the Navy and then multiplying by a single price-conversion factor. Because electricity prices vary throughout the country, this is not enough detail to provide solid benefit estimates for metering.

Figure 4 shows the estimated benefits from metering various percentages of the Navy's overall building square-footage in the United States excluding family housing. These calculations are very approximate. We assumed that the electrical costs for buildings were perfectly correlated with square-footage. We made no account for location or local electricity costs. We do not know whether the DUERS data include buildings earmarked for closure through BRAC.

For reference, we include figure 5 showing the cost estimates for metering various percentages of the Navy's overall building square-footage in the United States excluding family housing. This figure is identical to one discussed earlier in the paper.

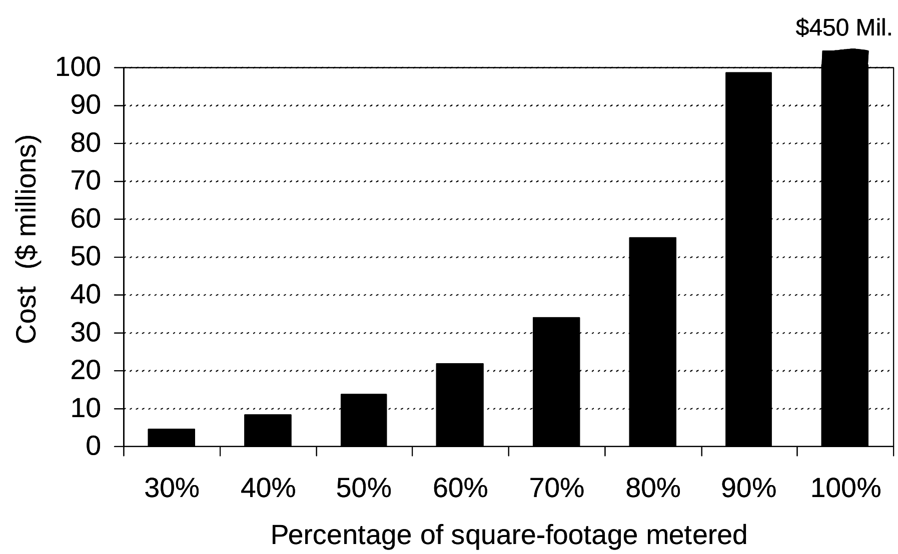
What we can tell from comparing the two figures is that the Navy should probably meter from 60 to 80 percent of its present square-footage. The main driving factor here is that the costs for metering a greater percentage of square-footage (assuming the Navy meters its

Figure 4. Estimated annual savings from metering different percentages of the square-footage of Navy buildings in the United States (excluding family housing)[a]



a. Estimates have been adjusted to account for buildings known to already have demand-interval meters.

Figure 5. Estimated cost to meter different percentages of the square-footage of Navy buildings in the United States (excluding family housing)[a]



a. Estimates have been adjusted to account for buildings known to already have demand-interval meters.

largest buildings first) start to increase tremendously as the subsequent buildings get smaller. Even if we assume that the estimates in figure 4 overstate the benefits, metering 60 to 80 percent of the Navy's building square-footage would still be optimal using most discount rates.

These comparisons are only for Navy facilities in the United States. Facilities abroad probably should be considered on a case-by-case basis. Metering facilities abroad will depend on local electricity prices and rate structures if the Navy is purchasing its electric power locally.

Conclusion

Information from electric meters can be used to save money in a military environment under current Navy management incentives. Data from the San Diego region show that buildings with demand-interval electric meters reduce their electrical kWh consumption by 5 percent and their electrical costs by 9 percent. Regionalized and working capital fund activities showed additional levels of savings when compared to non-regionalized, mission-funded activities.

Although these results are from one location, they are based on a rigorous and robust examination of real data. The results agree with general levels of savings found in the trade literature. Previous assertions that the military achieves much smaller savings from metering were based mostly on conjecture.

These levels of savings mean that it is cost-effective for the Navy to install demand-interval electric meters on many of its buildings even with higher-bound installation cost estimates. By focusing on its largest buildings, the Navy can meter most of its building square-footage and fulfill the mandates contained in pending congressional legislation.

Although specific metering decisions need to be made at the local level on a case-by-case basis, we estimate that, overall, it is cost-effective for the Navy to meter from 60 to 80 percent of its square-footage[14] in the United States. By metering its largest facilities and using higher-bound estimates, this could cost from $22 million for 60 percent of the Navy building square-footage in the United States to $55 million for 80 percent.

On the benefits side, the Navy was only able to provide us with data to support the broadest estimates. Assuming that the final legislation

14. Excluding family housing.

allows for a multi-year implementation, the Navy ought to have a roll-out strategy. It should start with the largest facilities at locations with the highest electricity rates and see how much meter installation actually costs and how much electricity can be saved.

To make full use of the information from demand-interval meters and achieve maximum savings, it is very important to have the right incentives. The Navy entity that pays the electricity bill should also be responsible for making energy conservation investments. They need to be able to see the full-cost trade-offs between conservation investments and long-term savings.

One important component of this cost visibility is to have activities be charged for their electricity using a realistic rate structure. In San Diego, the PWC charges for electricity using several different component rates. Tenants see these rates and each corresponding consumption level detailed on their bills; they also see their buildings' electricity usage profiles via Web-based software. In short, they see realistic rates and have the tools to efficiently adapt. Advanced meters help this process. Simplifying bills to unrealistic rate structures would send the wrong signals.

It would greatly encourage energy efficiency, if activities that conserve energy got to keep some of the savings. Currently, savings may be kept in the short-term within the fiscal year, but are usually taken away fully in subsequent years. Activities should be able to keep some of the savings for several years.

Appendix: Regression specifications

Data

Our primary data were utility billing records provided by the Navy Public Works Center (PWC) for the San Diego region.[15] We had monthly records from March 1997 through April 2003. During this period, the PWC was implementing and expanding its Computerized Utility Billing Integrated Control (CUBIC) system. By the end of the period, CUBIC included billing data for 2,400 tenants in more than 2,000 Navy buildings. In addition, during this period, the PWC was installing demand-interval electric meters and making consumption data directly available to tenants via their MV-Web network system. MV-Web lets tenants see their buildings' complete electricity-consumption profiles over the course of a day or week.

CUBIC allocates a base's electricity consumption among its tenants. Where buildings and tenants are individually metered, CUBIC uses those data to determine precise electricity bills. Sometimes, buildings are metered in clusters rather than individually; in these cases, CUBIC apportions the electricity known to be used by the cluster among the appropriate tenants using engineering models.

During the course of our data period, new demand-interval meters were installed, and many buildings switched from being metered in clusters to being individually metered and having their electricity consumption data available on the MV-Web. It is this changeover that

15. The billing data were for Navy facilities in the San Diego area including the Fleet Anti-Submarine Warfare School; the Fleet Industrial Service Center, San Diego; Naval Air Station, North Island; Naval Amphibious Base, Coronado; Naval Medical Center, San Diego; Naval Station, San Diego; Navy Outlying Landing Field; Old Town Campus; Point Loma Complex; Radio Station, Imperial Beach; and 1220 Pacific Highway.

allows the regression analysis to estimate reduced consumption when the demand-interval meter data became available to tenants.

Rate structure

The San Diego PWC uses a realistic rate structure to charge its customers for electricity. The rate structure has five components:

- Off-peak usage, which is the amount of electricity in kilowatt-hours (kWh) consumed from 10:00 pm to 6:00 am weekdays, and all day on weekends and holidays.
- Peak usage, which is the amount of electricity (in kWh) consumed from 11:00 am to 6:00 pm on weekdays during the summertime (from May 1 to September 30) and from 5:00 pm to 8:00 on weekdays during the wintertime (from October 1 to April 30).
- Semi-peak usage, which is the amount of electricity (in kWh) consumed in the summertime from 6:00 am to 11:00 am and from 6:00 pm to 10:00 pm; in the wintertime, the semi-peak period is from 6:00 am to 5:00 pm and from 8:00 pm to 10:00 pm.
- Coincident peak demand, which is the amount of power in kilowatts (kW) being used when San Diego Gas and Electric (SDG&E) has its system peak during the month; this is a momentary surge level that may occur at any time.
- Non-coincident peak demand, which is the amount of power (in kW) being used when the Navy base's usage peaks during the month; this is a momentary surge level that may occur at any time.

Each of these components has its own rate. The components and time frames coincide with SDG&E's rate structure. A tenant's total electricity bill is the sum of all these component rates multiplied by the appropriate usage levels. The bills break out each component charge for the tenant.[16] The rates themselves are set in advance through the working capital fund but reflect the true costs charged by SDG&E.

A few buildings had a sixth rate for electricity cogenerated by the base. Cogenerated power was extraordinarily expensive and was produced as part of overall military requirements; customers did not have any choice regarding consumption. For this reason, we excluded all cogenerated electricity and rates from the regressions.

Determining buildings with meters

To estimate which buildings had demand-interval meters and, therefore, could see their actual consumption levels, we used a formula based on the meter connections tracked in the CUBIC billing system. From the data, we could tell which meters were connected to specific buildings. Often buildings have more than one connection or feed. Over time, these connections changed as new meters were added. Only when all the meters connected to a particular building become advanced meters, are the tenants in that building able to get accurate demand profiles of their electricity consumption. We flagged those buildings connected only to demand-interval meters to examine whether they consumed less electricity than other buildings.

What we were not able to determine was whether buildings connected to time-of-use meters were metered individually or in small clusters. If all the meters connected to a building were demand-interval, then that building was categorized as "demand-metered." Although this may be a source of some error in the regressions, that error would produce savings estimates that were a little too low. This is because it would group buildings that were singly-metered for demand with those that were cluster-metered. Presumably, buildings that are singly metered receive more useful information than those metered in clusters.

16. The bills actually show the total kWh consumed and then add surcharges for peak and semi-peak periods. For the regressions, we calculated the corresponding total cost for a kWh consumed during the various periods.

Dummy variables

Each building has some unique characteristics that are stable over time. These fixed characteristics, which include its dimensions, basic design, year-built, and other factors, affect the building's overall energy efficiency. Therefore, we include a dummy variable for each building in the data set to account for all these fixed characteristics. The dummy variable would be each building's intercept in the regression.

The dummy variable with the demand-interval meter indicator would show how the building's intercept changes after the demand-interval meters are installed.

In addition, there are unique characteristics that would affect all tenants within a single billing period. These monthly characteristics include weather conditions in the San Diego area, region-wide management initiatives, and political priorities that affect all activities. To model these, we include a dummy variable for every billing period in the data.

Tenant classifications

Different activities in the Navy have different management structures. We tested to see whether these different structures produced different results for energy conservation. We classified the tenants into seven groups based on the entity that was responsible for paying the utility bills and making energy investments. These classifications were: mission-funded non-regionalized activities, regionalized activities, working capital fund activities, non-Navy military offices, private sector businesses operating on base, contractor offices on base, and government commercial enterprises (such as the Navy Exchange). Each classification had its own dummy variable with the mission-funded, non-regionalized activities being the base case.

Supplemental sources of heat

Some customer bills included charges for other sorts of utilities, such as natural gas or steam. When these charges appeared, we assumed that those customers had supplemental sources for heating and, therefore, would likely have lower electric bills during the winter months. We inserted a dummy variable to indicate buildings that have supplemental forms of heat in winter months from December through March.

Occupied space

Finally, we used occupied space data to adjust for the different amounts of square-footage that different tenants occupied. These data came from CUBIC and were measured by the San Diego PWC.

Regression models

Electricity consumption model

We used a logarithmic model to estimate electricity consumption for customers, based on the building being occupied, the amount of square-footage used, the price of electricity, supplemental sources of heat, the general classification of the tenant, and whether the building had demand-interval meter(s).

$$Ln(Electricity)_{c,t} = \alpha_i + \mu_t + \beta_1 Metered_{i,t} + \beta_2 Ln(P_{off-peak})_{c,t} + \beta_3 W_t Ln(P_{semi-peak})_{c,t}$$

$$+ \beta_4 S_t Ln(P_{semi-peak})_{c,t} + \beta_5 W_t Ln(P_{peak})_{c,t} + \beta_6 S_t Ln(P_{peak})_{c,t} + \beta_7 Ln(Occupied\ Space)_{c,t}$$

$$+ \beta_8 H_t Heating_{c,t} + \sum_{n=1}^{6} \gamma_n Payer\ Class_c + \varepsilon_{c,t}$$

Where:

$Electricity_{c,t}$ is the total amount of electricity measured in kilowatt-hours consumed by customer *c* in billing period *t*. Billing periods are monthly. This amount does not include electricity cogenerated by the Navy.

α_i is a dummy variable intercept for building *i*. Each customer *c* maps to a particular building. The dummy variable captures unique, unchanging attributes of building i. One building may contain several tenants, or customers, but roughly 90 percent of the buildings have a single tenant.

μ_t is a dummy variable intercept for billing period t. It captures unique attributes of that billing period that affect all of San Diego. These characteristics would include weather conditions, political conditions, and broad management initiatives.

$Metered_{i,t}$ is a dummy variable that is 1 if all the meters connected to building i at time t are demand-interval meters.

$P_{off\text{-}peak}$, $P_{semi\text{-}peak}$, and P_{peak} are the respective off-peak, semi-peak, and peak rates for electricity charged to customer c in billing period t.

W_t and S_t are dummy variables indicating winter and summer periods, respectively, as defined by SDG&E. W_t is 1 for billing periods from October through April; S_t is 1 for billing periods from May through September. We estimate these price effects separately because the peak and semi-peak time periods change between winter and summer. Consequently, it may be easier for customers to substitute away from peak and semi-peak consumption in one period than another. The off-peak rate period is the same throughout the year.

$Occupied\ Space_{c,t}$ is the amount of space in square-footage occupied by customer c at time t in building i. The square-footage had been measured by the San Diego PWC and is contained in CUBIC.

$Heating_{c,t}$ is a dummy variable indicating whether customer c at time t had a supplemental source of energy, such as natural gas or steam that could be used for heating. H_t is an indicator for billing periods in December through March when heat might be used. We would expect that during those months, customers with supplemental sources of energy would be using less electricity than others without supplemental energy sources.

$Payer\ Class_c$ indicates the general class of management entity that is responsible for paying the electric bill. It is a series of six dummy variable where each customer would fit into only one classification. The classifications used indicate regionalized activities, working capital fund activities, non-Navy military offices on base, private-sector commercial businesses operating on base, contractor offices on base, and government enterprises on base (such as the Navy Exchange). The base case with no dummy variable indicates mission-funded, non-regionalized activities.

β and γ indicate the coefficients that we are interested in. They will be estimated by the regression procedures and reported here.

$\varepsilon_{c,t}$ is the error term for the electricity consumed by customer c in billing period t.

Electricity consumption regression results

Table 6 contains the results of the regression model estimating total electricity consumption.

Effect of meters

The metering variable was highly significant. We also found it to be very stable through many regression model variations. Because we used a logarithmic model, the estimated coefficients of the dummy variables require a simple transformation to convert them into a percentage of savings. The formula is:

$$Estimated\ Savings = 1 - Exp(\beta_1)$$

The regression results in table 6 show that buildings with demand-interval meters correlate with a 5-percent reduction in overall electricity usage. The 95-percent confidence interval shows between a 3- and 7-percent reduction in consumption. A key factor driving the reliability of these results is that for most of the metered buildings, we have observations both before and after the meters were installed.

Prices

Most of the price parameters were significant, except for the winter peak rate. However, some of the signs and magnitudes of the price coefficients were unreasonable. Ideally, we would expect all the price coefficients to be negative. Also, the estimated price coefficients for this logarithmic regression are actually elasticities, indicating the

Table 6. Regression results for estimating total electricity consumed

Parameter	Estimated coefficient	Estimated standard error
$\text{Metered}_{i,t}$**	- 0.0514	0.0102
Ln $(\text{Price}_{\text{off-peak}})_{c,t}$**	- 2.2092	0.5226
Winter Ln $(\text{Price}_{\text{semi-peak}})_{c,t}$**	2.3494	0.6517
Summer Ln $(\text{Price}_{\text{semi-peak}})_{c,t}$**	2.4796	0.6076
Winter Ln $(\text{Price}_{\text{peak}})_{c,t}$	- 0.1788	0.2324
Summer Ln $(\text{Price}_{\text{peak}})_{c,t}$*	- 0.3182	0.1311
Ln $(\text{Occupied Space})_{c,t}$**	0.9832	0.0036
$\text{Heating}_{c,t}$**	- 0.1121	0.0089
Regionalized activity**	- 0.1287	0.0153
Working capital fund activity**	- 0.1351	0.0161
Non-Navy military activity**	- 0.1678	0.0277
Commercial business**	0.3068	0.0422
Government enterprise**	0.1183	0.0236
Contractor office**	- 0.6522	0.0630

Dependent variable:	Ln $(\text{Electricity})_{c,t}$
Number of observations:	103,870
Total number of parameters, including building and billing period intercepts:	1,930
R-square:	0.8673

*. Significant at the 2 percent level.
**. Significant at the 1 percent level or better.

percentage change in electrical consumption for a 1-percent change in prices. The magnitudes for these effects appear to be too great. Much of the reason is that the various rates are likely to be correlated. This is a problem when there are multiple rates for a commodity. Other studies have also encountered this problem when modeling prices [17].

However, the parameter estimates we are interested in are not very sensitive to these price variables. Running the same regression with no price variables at all produces almost identical results for the other parameter estimates.

Occupied space

The occupied space coefficient was very highly significant. We would expect electricity consumption to be proportional to a tenant's occupied space, and indeed the coefficient came out very close to 1.

Heating

Heating was also very highly significant. Using the formula above to convert into percentages, we find that tenants with supplemental sources of heat used roughly 11-percent less electricity during the winter months compared with tenants without supplemental heat.

Payer classifications

All the payer classifications were significant. Using the formula above to calculate percentages, regionalized activities used 12-percent less electricity than did non-regionalized, mission-funded activities. Working capital fund activities used about 13-percent less electricity than did the non-regionalized, mission-funded activities.

The commercial businesses on base and government commercial enterprises used substantially more electricity than did other activities. This is to be expected because they must keep their shops comfortable and well-lit for customers.

The one unexpected result in the payer classification coefficients was that contractor offices and non-Navy military activities used unreasonably small amounts of electricity. This is probably due to the fact that there were very few observations in each of these two groups.

One factor driving the regression results for the payer classifications was that during the time period being looked at, a relatively large number of buildings changed tenants. The regression procedures compared the electricity used in buildings as tenants with different management structures moved in and out.

Electricity cost model

To estimate the effect of demand-interval meters on electricity costs, we ran similar regressions substituting total electricity cost for the dependent variable. This total cost includes all five components but does not include cogenerated power costs. All the variables are defined as in the previous model.

$$Ln(Electric\ Cost)_{c,t} = \alpha_i + \mu_t + \beta_1 Metered_{i,t} + \beta_2 Ln(P_{off-peak})_{c,t} + \beta_3 W_t Ln(P_{semi-peak})_{c,t}$$

$$+ \beta_4 S_t Ln(P_{semi-peak})_{c,t} + \beta_5 W_t Ln(P_{peak})_{c,t} + \beta_6 S_t Ln(P_{peak})_{c,t} + \beta_7 Ln(Occupied\ Space)_{c,t}$$

$$+ \beta_8 H_t Heating_{c,t} + \sum_{n=1}^{6} \gamma_n Payer\ Class_c + \varepsilon_{c,t}$$

Table 7 shows the result of this regression.

Effect of meters

As with the electricity consumption model, the metering variable was highly significant with cost also. Again, the estimate was stable through many variations in the model. Converting the estimates to percentages, we find that buildings with demand-interval meters have a mean reduction in electricity cost of 9 percent. The 95-percent confidence interval for savings runs from 6.6 percent to 11.5 percent.

The reason the savings percentage is greater for cost than for kWh consumption is because a greater proportion of the reductions came from high-cost rate periods.

Table 7. Regression results for estimating total electricity costs

Parameter	Estimated coefficient	Estimated standard error
$\text{Metered}_{i,t}$*	- 0.0951	0.0136
Ln $(\text{Price}_{\text{off-peak}})_{c,t}$*	- 1.7960	0.6968
Winter Ln $(\text{Price}_{\text{semi-peak}})_{c,t}$*	2.5503	0.8666
Summer Ln $(\text{Price}_{\text{semi-peak}})_{c,t}$*	2.4368	0.8092
Winter Ln $(\text{Price}_{\text{peak}})_{c,t}$	- 0.0620	0.3064
Summer Ln $(\text{Price}_{\text{peak}})_{c,t}$	- 0.2772	0.1744
Ln $(\text{Occupied Space})_{c,t}$*	1.0907	0.0046
$\text{Heating}_{c,t}$*	- 0.1306	0.0118
Regionalized activity*	- 0.0826	0.0203
Working capital fund activity*	- 0.1373	0.0215
Non-Navy military activity	- 0.0312	0.0366
Commercial business*	0.3528	0.0566
Government enterprise*	0.1901	0.0313
Contractor office*	- 0.8435	0.0846

Dependent variable:	Ln $(\text{Electric Cost})_{c,t}$
Number of observations:	107,492
Total number of parameters, including building and billing period intercepts:	1,997
R-square:	0.8274

*. Significant at the 1 percent level or better.

Prices

Again, some of the price coefficients were too large. Also, the coefficient for the winter peak price was not significant, and the coefficient for the summer peak price was near-significant (at the 11-percent level). These results were due to having multiple prices that are somewhat correlated with each other. When the regression is run without any prices, the estimates of the remaining parameters remain almost identical.

Occupied space

Again, the occupied space coefficient was very highly significant and fairly close to 1, as would be expected.

Heating

The heating coefficient was very highly significant. Tenants with supplemental sources of heat spent about 12-percent less on electricity in the winter months than they would have spent without supplemental heat.

Payer classifications

The payer classifications for regionalized activities and working capital fund activities were both very significant. Compared with non-regionalized, mission-funded activities, the regionalized activities spent 8-percent less on electricity and the WCF activities spent 13-percent less.

As expected, government commercial enterprises and commercial businesses on base spent substantially more on electricity than did other activities, roughly 20 percent and 40 percent more, respectively.

The coefficient for non-Navy military activities was not significant. The coefficient for contractor offices was significant but showed unreasonably small electricity costs. These effects were likely due to the small number of tenants in each category.

Robustness and data quality

As mentioned above, the regressions were very robust through many variations. Choosing which price parameters to use was problematic. We only left out the coincident and non-coincident rates, because they are for momentary demand levels at times that are not fully predictable. However, the parameter estimates we are interested in are not sensitive to prices. Tables 8 and 9 show the electricity consumption and electricity cost regressions without any price variables. The results are almost identical to the previous regressions.

Table 8. Regression results for estimating total electricity consumed without price parameters

Parameter	Estimated coefficient	Estimated standard error
$\text{Metered}_{i,t}^{*}$	- 0.0504	0.0102
$\text{Ln (Occupied Space)}_{c,t}^{*}$	0.9831	0.0036
$\text{Heating}_{c,t}^{*}$	- 0.1122	0.0089
Regionalized activity*	- 0.1290	0.0153
Working capital fund activity*	- 0.1338	0.0161
Non-Navy military activity*	- 0.1681	0.0277
Commercial business*	0.3063	0.0422
Government enterprise*	0.1175	0.0236
Contractor office*	- 0.6524	0.0630

Dependent variable:	$\text{Ln (Electricity)}_{c,t}$
Number of observations:	103,870
Total number of parameters, including building and billing period intercepts:	1,925
R-square:	0.8672

*. Significant at the 1 percent level or better.

Table 9. Regression results for estimating total electricity costs without price parameters

Parameter	Estimated coefficient	Estimated standard error
$\text{Metered}_{i,t}$*	- 0.0955	0.0136
Ln $(\text{Occupied Space})_{c,t}$*	1.0906	0.0046
$\text{Heating}_{c,t}$*	- 0.1297	0.0118
Regionalized activity*	- 0.0828	0.0203
Working capital fund activity*	- 0.1346	0.0215
Non-Navy military activity	- 0.0316	0.0366
Commercial business*	0.3524	0.0566
Government enterprise*	0.1891	0.0313
Contractor office*	- 0.8437	0.0847

Dependent variable:	Ln $(\text{Electric Cost})_{c,t}$
Number of observations:	107,492
Total number of parameters, including building and billing period intercepts:	1,992
R-square:	0.8273

*. Significant at the 1 percent level or better.

The regression estimates we presented earlier in the main body of this paper regarding the component consumption periods (peak, semi-peak, and off-peak) were not as robust as the total consumption or cost estimates. However, they did stay within a reasonably close range. Those estimates were presented less formally to show generally where electricity savings were occurring.

Data concerns

As with most real-world data sets, this one was not perfect. There were many incomplete records. Some were missing certain consumption periods. Some showed costs in the coincident and non-coincident kW fields, but no kWh being consumed. Some records showed only off-peak electricity consumption. This is why the number of observations varied for the regressions in tables 6 through 9.

The regressions reported in this paper used all the data possible. We did not pick and choose which records were reasonable. We did not drop any outliers. We ran some other regressions, not reported here, where we did drop some incomplete records, but this appeared to make little or no difference in the final results.

In the billing data, the proportion of off-peak kWh's consumed compared to overall consumption was much more than we had expected. Some of those data may be questionable and indicate that some peak consumption in buildings without advanced meters had been classified as off-peak consumption. If this was the case, then it would tend to bias either the consumption-savings regression estimate as being too high or the cost-savings regression estimate as too being low. In other words, if this is truly an error in the data, it would mean that the spread between the 5-percent kWh savings and the 9-percent cost savings should actually be larger.

Unfortunately, we were not able to completely map out which buildings were metered singly and which in clusters. Also, for buildings without demand-interval meters, we could not tell whether they had older monthly meters or no meters at all. We would like to have had this specific information, but we do not feel it is essential to the validity of the result that demand-interval meters help save significant amounts of energy.

It is always preferable to have a perfect data set. However, these billing data were quite good overall, and the results were remarkably robust. This indicates that the regression results are very credible.

References

[1] U.S. House of Representatives, *H.R. 6, To enhance energy conservation and research and development, to provide for security and diversity in the energy supply for the American people, and for other purposes, Section 11003 Energy use measurement and accountability*, as reported by the U.S. Library of Congress at http://thomas.loc.gov/ on 31 Aug 2003

[2] U.S. Senate, *H.R. 6, Energy Policy Act of 2003, Section 912 Energy use measurement and accountability*, as reported by the U.S. Library of Congress at http://thomas.loc.gov/ on 31 Aug 2003

[3] John McBride. "Energy Metering: Costly Overhead or Cost-Effective Conservation?" *Energy User News*, 18 May 2002

[4] Glenn H. Ackerman and Samuel D. Kleinman. *Creating a "Revolution in Business Affairs" in DoD*, Dec 1997 (CNA Research Memorandum 97-126.10)

[5] U.S. House of Representatives, *H.R. 6, To enhance energy conservation and research and development, to provide for security and diversity in the energy supply for the American people, and for other purposes, Section 16061 Real-time pricing and time-of-use metering standards*, as reported by the U.S. Library of Congress at http://thomas.loc.gov/ on 31 Aug 2003

[6] U.S. Senate, *H.R. 6, Energy Policy Act of 2003, Section 241 Real-time pricing and time-of-use metering standards*, as reported by the U.S. Library of Congress at http://thomas.loc.gov/ on 31 Aug 2003

[7] Naval Facilities Engineering Command, S*ustainable Design Case Study: Naval Facilities Engineering Command Headquarters Building*, Jul 1990

[8] Donald L. Hadley. *Energy Savings Estimates from Sustainable Design Concepts for Naval Facilities Engineering Command Headquarters Building Washington Navy Yard, Washington, D.C.,* Apr 2001 (Pacific Northwest National Laboratory)

[9] Naval Surface Warfare Center, Crane, Indiana, *2002 Annual Energy Savings Verification Report*, Oct 2002 (prepared by Noresco, contract no. N47408-97-D-0402, delivery order 002)

[10] Naval Air Facility, Key West, Florida, *Caribbean Area Energy Savings Performance Contract Annual Verification Report Year Three*, Nov 2002 (prepared by Noresco, contract no. N47408-98-D-2007, delivery order 002)

[11] Naval Station Roosevelt Roads, Ceiba, Puerto Rico, *Annual Verification Report Year One*, Jun 2002 (prepared by Noresco, contract no. N4708-98-D-2007)

[12] Portsmouth Naval Shipyard, *Measurement and Verification Report Year 2, Quarter 3 (July 1, 2002 - September 30, 2002) Report #7*, Nov 2002 (prepared by Select Energy Services, Inc., contract no. DACA87-97D-0068)

[13] Marine Air/Ground Task Force Training Center (MAGTFTC), *Twentynine Palms, California, MAGTFTC Twentynine Palms Project 1 Year One Measurement and Verification Report October1, 2001-September 30, 2002,* (prepared by Johnson Controls, contract no. DACA87-97-0069, delivery order EJP2)

[14] Paul Gromer. "The Case for Advanced Metering." *E Source: Energy Information and Communication Service* EIC-16, Aug 2001

[15] U.S. Department of Energy, Federal Energy Management Program, *FEMP Report: Advanced Utility Metering,* Nov 2002 (prepared by the National Renewable Energy Laboratory and the Architectural Energy Corporation, NREL task order number KADC-0-30423-06)

[16] Naval Facilities Engineering Service Center, Energy Program Division, *Department of the Navy Energy Program Management Study and Data Quality Review*, Dec 2002 (Prepared by Strategic Management Initiatives, Inc.)

[17] G. S. Maddala et al. "Estimation of Short-Run and Long-Run Elasticities of Energy Demand from Panel Data Using Shrinkage Estimators." *Journal of Business and Economics Statistics* 15, Jan 1997: 90-100

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CRM D0008909.A2 / Final

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